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Summary

Introduction

Portable medical technologies support delivery of care to deployed forces in theater operations and in Operations Other Than War. The Mobile Medical Monitor (M3) concept creates a clinical and information support system composed of a standard battlefield computer with an integrated clinical sensor suite capable of data storage and forwarding.

Objective

The primary objective of this report is to document the evaluation of the M3(B) workstation. The evaluation was conducted to determine the extent to which the M3(B) requirements met the primary objectives of increased clinical capabilities, increased productivity, increased provider satisfaction, and reduced footprint. Evaluation was conducted and recorded for the clinical sensors and the management information support capabilities.

Method

The M3(B) was tested in laboratory and field environments. Laboratory testing was conducted to evaluate the accuracy and reliability of individual components and of the fully integrated system. Observations, logs, and objective measures were used to record findings. Training in the use of M3(B) was then given to two groups of medical personnel of the 1st Medical Battalion, Camp Pendleton, CA. Comments from the users were recorded. Field-testing was conducted during a casualty exercise held by the 1st Medical Battalion. During the exercise, observations and objective measures were gathered. Surveys, interviews, and after-action discussion groups provided additional data.

Results

Results from laboratory testing demonstrated that the M3(B) met the design criteria for hardware and software. Battery life averaged one hour instead of the anticipated two hours. Data from field observations showed that patient registration using the M3(B) was 40% faster than using manual methods. M3(B) blood pressure and pulse oximetry readings averaged one seventh the time of conventional methods. Annotations and video capture were frequently used. Ultrasound and the rhinolaryngoscope were not extensively used. The Ultrasound software was found to require a higher level of training than had been provided. The users reported that the M3(B) was easy to learn, although they thought set up was difficult. The M3(B) was judged to increase productivity by improving patient tracking and allowing caregivers to make rapid diagnoses.

Discussion and Recommendations

Additional ruggedization of components and more efficient packaging are recommended. Better packaging of the M3(B) should result in reduced weight, cube, number of individual items, and the number of connections. Additional training in the use of the Windows environment and the clinical application software is needed for M3(B) workstation users. The ability to monitor multiple patients, write information onto the Personal Information Carrier and into a relational database should be included to enhance clinical care and improve information management. A network-centric approach to providing medical care and transmission of medical information is recommended.

Evaluation of the Mobile Medical Monitor (M3) At Forward Levels of Care

Introduction

The health service support mission is to minimize the effects of wounds, injuries, and disease on unit effectiveness, readiness, and morale. Traditional concepts of battlefield trauma management have relied on well-defined echelons of care, usually located at increasing distances from active areas of combat. Very limited technology was provided at the front line. Usually the main option for the critically injured in forward areas was evacuation to a relatively distant facility for surgery. Monitoring of vital signs was performed with simple equipment and could be difficult in the noisy and unstable environment of a helicopter. Monitoring also could be problematic during air transport of multiple patients. Because of delays, it could be difficult or impossible to deliver all critically injured patients to a surgical facility early enough to avoid irreversible deterioration.

In addition, new and evolving types of Marine Corps missions require troops to be highly dispersed, very mobile, and flexible enough to respond to changing conditions. These issues are now being addressed by deployment of surgical units to forward areas and employment of reliable personal computer-based tools for monitoring vital signs, pulse oximetry, electrocardiogram (ECG), and video imaging. Portable ultrasound and other types of rapid diagnostic imaging are also under consideration for use in forward areas. With the Mobile Medical Monitor (M3) Workstation, the Navy has initiated a process to assemble and deploy microelectronic, noninvasive clinical sensors and medical information technology capabilities in a rugged, modular unit for field use.

The M3(B) concept creates a clinical and medical information support system based on the standard U.S. military battlefield personal computer, the Lightweight Computer Unit (LCU) shown in Figure 1. A suite of clinical sensors, integrated with the LCU and its accompanying administrative and communications software, permits a portable system that can gather information from local medical monitoring units and manage and communicate information by telecommunications technology. Clinical sensors include vital signs monitors such as noninvasive blood pressure, ECG, pulse oximetry, and medical images (i.e., scopes, Ultrasound/Doppler and color photography). Medical information support capabilities include M3(B) data storage and transmission, medical databases, access to data storage devices (such as CD-ROM for medical data), office automation software, communications software, communications system interfaces, Theater Medical Core Services (TMCS)[1] functionality, and theater-based report generation. A key strategy for implementing the M3(B) concept is the use of "evolutionary integration," the process by which emerging technologies and capabilities are leveraged to enhance rapidly evolving user requirements.

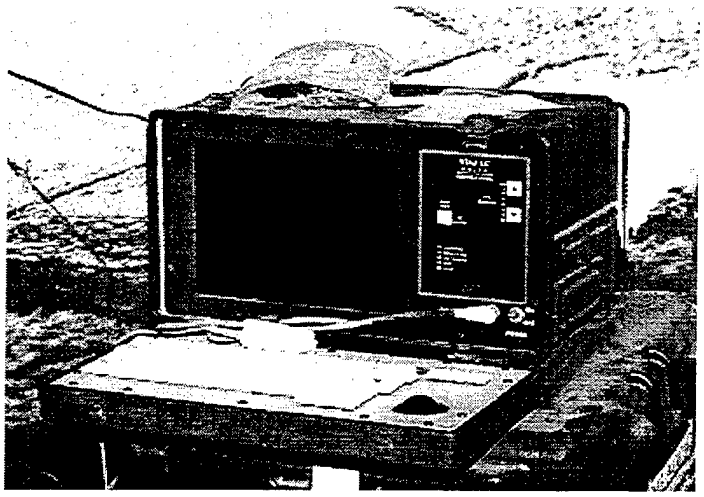

Figure 1. The M3(B) Workstation

Background

The M3(B) employs emerging hardware and software technologies to provide medical monitoring capabilities not normally possible in far forward environments. By centralizing and automating all clinical data collection, storage, and transmission, the M3(B) simplifies and accelerates clinical data management. The M3(B)'s ability to communicate useful, quality medical information to higher echelon care facilities in standardized and legible electronic format supports rapid consultation and affords enhanced resolution of medical emergencies. Intuitive hardware setup and on-screen navigation features allow the medical provider unprecedented clinical capability, data flexibility, and overall usefulness that exceed the capability of traditional medical monitoring equipment.

In early 1996, Science Applications International Corporation (SAIC) management concentrated on obtaining Food and Drug Administration (FDA) acceptance of the M3(B) concept using the M3(A) prototype. The M3(A) combined the LCU V2A2 computer with three FDA-approved medical sensors, modems, a video camera, commercial-off-the-shelf (COTS) software applications, and the medical sensor display software. Working with the FDA and representatives of the Department of Defense (DOD), including the Naval Medical Information Management Center (NMIMC), SAIC submitted a request to the FDA for approval of the M3(A) Basic Vital Signs Monitoring Configuration in September 1996. The Navy M3(B) program is the first step toward making the M3(B) concept a reality and the M3 workstation represents the next generation.

In FY97, the Naval Health Research Center (NHRC) formed a team to integrate additional clinical capability, improve the graphic user interface (GUI), and increase the store-and-forward potential (i.e., the ability to accumulate and store data and then transmit it at a later time). Development and integration were performed by SAIC and its

subcontractor, Litton Data Systems Division. *MTS Technologies, Inc.* was responsible for program support and test and evaluation.

During development of the M3(B), the GUI was improved and refined to make it easier to use by medical personnel at forward treatment facilities. The design guidelines were based on input gathered from many sources: M3(A) demonstrations and exercises at the 1st and 2nd Medical Battalions; the I, II, and III Marine Expeditionary Forces; and during the Tandem Thrust '97 and Kernel Blitz '97 exercises. The GUI and the added rhinolaryngoscope, Doppler ultrasound, Global Positioning System (GPS), and Personal Information Carrier (PIC) were designed to improve patient care as well as to reduce overall footprint at a surgical company.

Objective

The purpose of this report is to document the evaluation of the M3(B) workstation, including clinical application, usefulness, practicality, configuration, ruggedness, and training requirements. The primary objectives of the M3(B) are to (a) increase clinical capabilities at far forward and remote areas of care, (b) increase productivity and maintain medical readiness, (c) increase provider satisfaction, and (d) reduce the unit's footprint. The M3(B)'s capabilities were evaluated in both laboratory and field settings.

The M3(B) workstation capabilities shown in Table 1 were evaluated. Seventeen capabilities were identified within the design guidelines. All but four were integrated: multi-patient monitoring (MPM), PIC write, diagnostic ECG software, and blood gas assessment. The technical solution for MPM could not be performed within the time frame of the current contracts. The PIC write capability was not incorporated because it required conversion of software codes proprietary to another company. Diagnostic ECG software is a COTS product that only exists in the Windows '95 version; an NT® version does not yet exist. Blood gas assessment was not included because of its invasive nature and the need for external chemical agents.

Table 1. M3(B) Capabilities

Capability	Included in M3(B) Design	Evaluated
ECG	Yes	Yes
Blood Pressure	Yes	Yes
Pulse	Yes	Yes
Pulse Oximetry	Yes	Yes
MPM	No	No
PIC read-write	Read – only	Yes
Ultrasound with Doppler	Yes	Yes
Imaging	Yes	Yes
Navy Medical Configuration Definition for COE	Yes	Yes
Diagnostic ECG Software	No	No

Capability	Included in M3 (B) Design	Evaluated
GUI	Yes	Yes
Patient record	Yes	Yes
Temperature (manual entry)	Yes	Yes
General scope/nasopharyngeal	Yes	Yes
GPS	Yes	Yes
Blood gas assessment	No	No
Data transmission (TMCS)	Yes	Yes

Clinical Sensors

Clinical sensors on the M3(B) are devices designed to capture and measure specific patient physical conditions and parameters. The M3(B) operational main screen, which accesses and displays the sensor data, is shown in Figure 2.

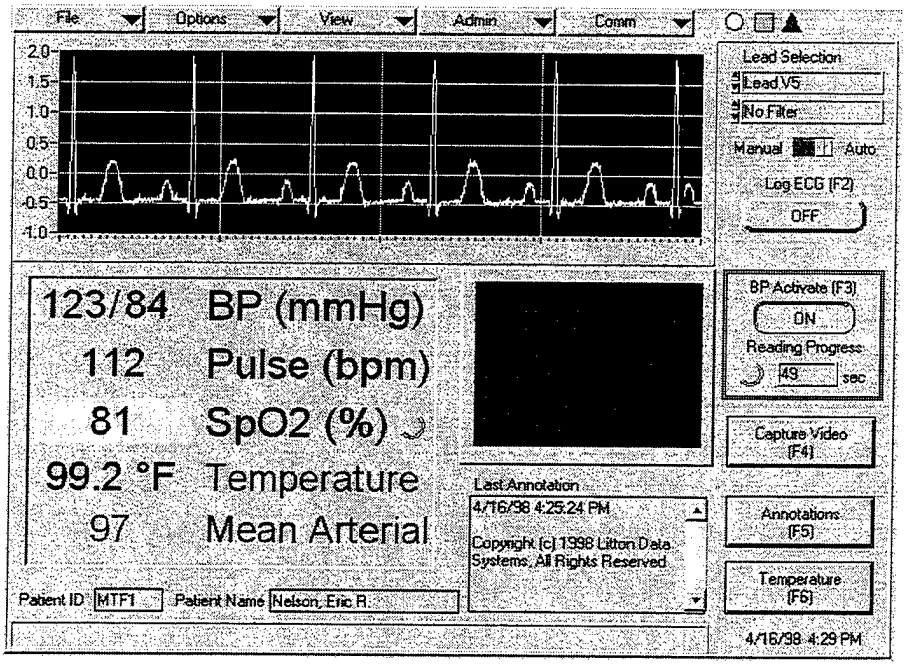

Figure 2. M3(B) Main Screen

3- or 12-Lead ECG Sensor

The ECG monitor consists of either 3 or 12 leads, with disposable electrode patches on the end of each lead that affix to the patient. This sensor is a standard monitoring tool for many patient conditions. The instrument provides the user with a display of the patient's cardiac rhythms. It can provide the immediate analysis of cardiac rate and rhythm, crucial in the analysis of all trauma patients and in the performance of all Advanced Cardiac Life Support and Advanced Trauma Life Support protocols. This sensor, manufactured by Pulse Biomedical, is included in the M3(B) configuration.

Noninvasive Blood Pressure Sensor

The noninvasive (nonsurgical) blood pressure (BP) sensor measures blood pressure using an inflatable arm cuff, a pump, and a pressure meter. This instrument gives the user readings of the patient's systolic rate, diastolic rate, and pulse. In emergency situations, the blood pressure can signal the presence of circulatory collapse or shock and will indicate when fluid resuscitation is necessary. This sensor, manufactured by Spacelabs Medical, is integrated on the M3(B) with an external blood pressure cuff.

Pulse Oximetry Sensor

The pulse oximetry sensor is a small device placed on the patient's finger and provides the user with readings of pulse rate and oxygen concentration in the blood. The standard pulse oximeter, which avoids the need for painful and invasive blood gas determination, provides immediate and continuous readings as a percentage of oxygen in the blood. It also permits monitoring during oxygen therapy. Lung function and tissue oxygenation are crucial for avoidance of hypoxic (oxygen deprivation) injury. The sensor, manufactured by Nellcor, is included in the M3(B) configuration.

Temperature Input

Patient temperature is a standard vital sign. Temperatures are taken manually with a thermometer and are recorded into the patient record using the keyboard on the M3(B) workstation and displayed in Fahrenheit or Celsius. Entries are retained as part of the patient history for review, and store and forward.

Ultrasound with Doppler

The ultrasound with Doppler is a hand-held probe used to determine the presence or absence of blood in body cavities, confirm vascular integrity, and locate substantive shrapnel or missile fragments. A signal is sent from the crystal at the probe's tip and is reflected back again by red blood cells. The red blood cells modify the frequency according to their velocity. In all cases, the higher the pitch of the reflected sound, the greater the blood flow velocity whether toward or away from the probe. This frequency shift is then converted into an audible signal and amplified. Doppler output is always an audio signal with a pitch proportional to the velocity of the blood flow and loudness proportional to the amount of blood. The ultrasound emits high-frequency sound waves from a transducer, which is placed in contact with the patient. Repetitive arrays of ultrasound beams scan the patient and are reflected back onto the same transducer. The information obtained from different reflections is analyzed and transformed into a video signal, similar to an x-ray, and displayed on the M3(B) screen. "Real-time monitoring" and storing and forwarding the data to the receiving or consulting medical treatment facility (MTF) and other personnel or units involved in the evacuation process can maximize the value of this capability. This capability is not included in the M3(A)

configuration, but the GPS5000, manufactured by Perception Ultrasound, is included in the M3(B) configuration.

Nasopharyngoscope

The nasopharyngoscope, also called the rhinolaryngoscope, is a hand-held device consisting of a sensor that is inserted into the ear, nose, throat, or other opening and provides the user with a direct or video view. Scopes of this technical capability use fiber optic technology to view, capture, and transmit images with a minimally invasive procedure for a wide variety of clinical situations. This capability is not included in the M3(A) configuration, but a RL150, manufactured by Welch-Allyn, is included in the M3(B) configuration.

Clinical Support Capabilities

A number of M3(B) capabilities capture patient data, either physical or demographic, and summarize and display them in a manner that provides the caregivers additional information in support of clinical decision-making processes. These clinical support capabilities are described.

Imaging Capability

An external camera manufactured by Best Data Smart One provides the ability to capture images. The image can be incorporated into an electronic record and transmitted to a different location. The M3(A) has this capability for still images. With the addition of the ultrasound with Doppler, the nasopharyngoscope and its camera, the M3(B) provides enhanced clinical imaging capability.

M3(B) Data Capture and Clinical Data Display

M3(B) provides the capability to capture, process, and display patient information and imagery in an organized, form-oriented document. The software allows the medical provider to view selected data on the LCU screen, review stored data, identify significant data elements, reproduce these data, and create an abbreviated discharge summary. The user interface allows the operator to access and move data easily. The M3(B) also provides the ability to create annotations for the vital signs data and captured images that are available for review at any time. These annotations are retained in the record and are forwarded with the patient data in the Abbreviated Discharge Summary.

Personal Information Carrier (SmartCard) Reader

In this case, the term "SmartCard" refers to a generic, non-specific card format. SmartCard is an integrated circuit chip card capable of holding an individual's personal demographic information. The technology provides patient data privacy and security through the use of password protection. Health care providers are given basic readiness information furnished by the SmartCard such as personal demographic and blood type

information. Further development will include the ability to access other information such as allergies, medications, immunizations, and chronic medical conditions.

The SmartCard reader, manufactured by GEMPLUS, is an external module that plugs into the M3(B) LCU serial port. It is powered either from a connection to the rear of the M3(B) or by its internal 9 VDC battery. The SmartCard is inserted into the reader and patient data are automatically entered into the computer. Since no manual data entry is required, the SmartCard reader allows for timely registration into the health care system while reducing error rate.[2] During the treatment of casualties in the field, fast and accurate initiation of an electronic patient encounter record, location, and critical medical encounter information are extremely valuable.

Global Positioning System

The GPS, manufactured by Rockwell Collins Division, is an external module that plugs into the M3(B) LCU. It is powered either by its internal battery or from a converter connected to 60 Hz, 110 VAC utility power. The GPS uses satellite technology and provides an exact latitude-longitude location of the M3(B) unit which, along with the time of observation, is entered into the patient record and displayed on the LCU. These data are important for patient evacuation, tracking, and record keeping requirements.

Management Information Support Capabilities

The M3(B) computer provides powerful tools for data gathering, sorting, archiving, displaying, storing and forwarding. These management information support capabilities are summarized as follows.

V2L2 Lightweight Computer Unit

The LCU, manufactured by Litton Data Systems Division, is a lightweight, ruggedized, portable Intel Pentium-based computer. This computer serves as the platform for all peripheral plug-ins, for the operation of all software applications, and for all transactions. It is powered either by its internal battery or its converter from either 60 Hz, 110 VAC utility power or 12 VDC vehicle power.

Microsoft Windows NT®

Microsoft Windows NT® 4.0 is the operating system installed on the LCU. The DOD has selected the Windows NT® operating system as the common operating environment (COE). The M3(B) workstation is intended to operate in that COE functional environment.

M3(B) Data Transmission

Patient information and data elements captured by the M3(B) can be transmitted to other medical care facilities through electronic mail applications and TMCS. TMCS is a low-

bandwidth, secure web-based medium for consolidating medical command and control. It provides theater-based reporting capability for patient tracking, facility bed utilization, Defense Blood Support System (DBSS), and disease surveillance. This application allows store and forward communications on a Windows NT® platform. TMCS and its associated communications option were utilized in an operational setting at the Cobra Gold Exercise in Thailand, May 1998 and the results will be presented here.

Graphic User Interface

Although GUI is not a specific application, it is important to the overall functioning of the M3(B) system. The GUI is an on-screen display that allows the user to view and manipulate information resident on the LCU and those data being sent to the LCU by way of a sensor or sensors. This feature provides a comfortable level of user-friendliness that allows the operator to navigate smoothly through menus and tools displayed on the LCU screen. By navigating with a mouse (trackball), the user can enlarge views, display various viewing options, select various sensor data to view, save and store information, and forward information. Integrated with Windows NT®, GUI provides simpler, quicker, more efficient processing of all transactions.

Method

Scope of the Evaluation

Laboratory and field-testing of the M3(B) Workstation, its components, and interactions were conducted. Laboratory testing evaluated accuracy and reliability of the individual components and the fully integrated system. Field-testing consisted of casualty exercises at Camp Pendleton with the Charlie Company of the 1st Medical Battalion and its Medical Augmentation Program (MAP) personnel, and the Medical Education and Training Services (METS) personnel. The casualty flow was designed to reflect the types of patients expected in Navy/Marine deployments. The potential users were provided a realistic field experience. Caregivers were given hands-on M3(B) training from the user manual. The field-testing involved a medical exercise at a far-forward MTF. Functionality of individual sensors with the M3(B), use of clinical support capabilities, and management information support capabilities were evaluated. Surveys and discussion groups were used to gather users' perceptions regarding ease of use and practicality of the M3(B) system. The discussion groups included 16 Charlie Company personnel and 30 MAP personnel following their M3(B) training and the casualty exercise. Surveys were administered to physicians, nurses, and corpsmen. Additionally, comments were solicited from personnel regarding the M3(B)'s data transmission capabilities using TMCS during the Cobra Gold Exercise in Thailand May 1998.

Figure 3 outlines the objectives, measures, and methods used in the evaluation of the M3(B) workstation. In this figure, for example, it can be seen that increased user satisfaction was evaluated using the participants' perceptions of usefulness. Specific M3(B) evaluation criteria are summarized in Appendix B.

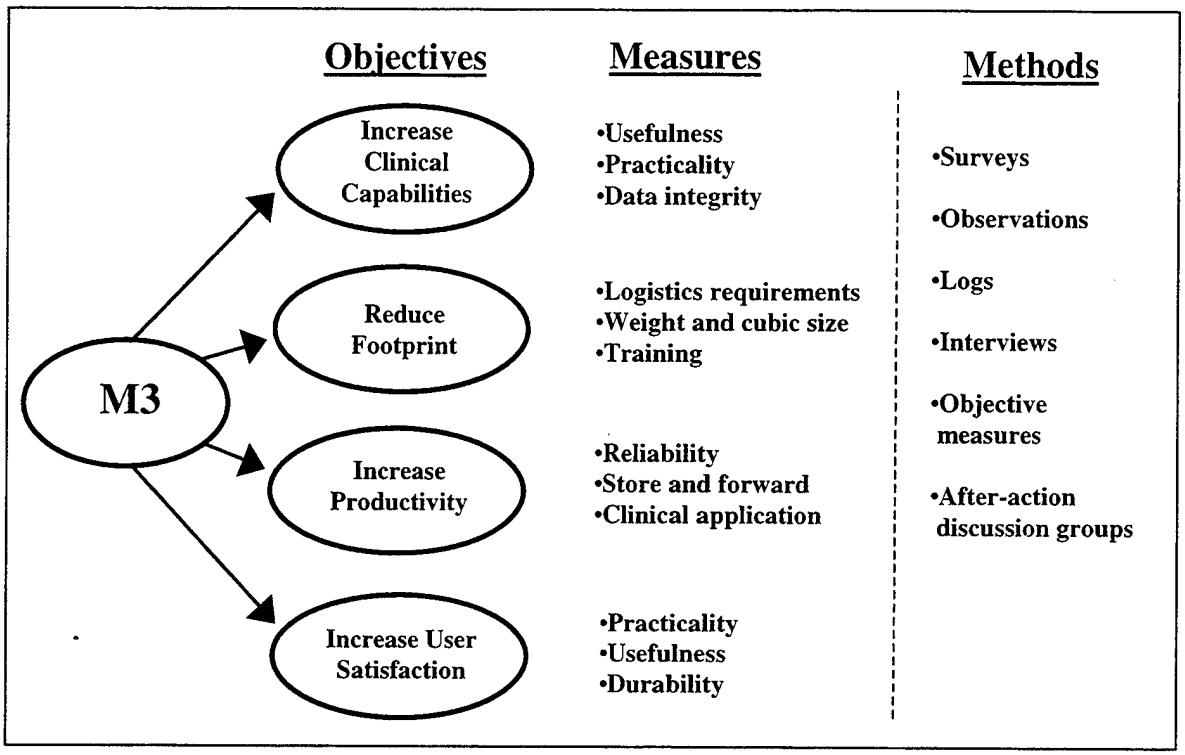

Figure 3. Test and Evaluation Approach

Laboratory Testing

Laboratory testing of M3(B) was conducted in two phases. First, acceptance testing was conducted. Second, testing using the sequence of operations outlined in the User Manual was performed.[3] This testing was designed to exercise the capacity and robustness of the unit as well as to explore the GUI for redundancies, error-prone displays, ease of entering and exiting applications, ease of correcting input errors and mistakes, and power consumption. This was accomplished by proceeding step-by-step through the User Manual. The measures developed for this portion of testing were intended to capture the time required for an operator to perform sequential tasks, and to gather user perceptions of the M3(B)'s usefulness and practicality. The data collection sheets are shown in Appendix C.

M3(B) Training

Two groups of medical personnel were trained at Camp Pendleton in the use of M3(B). The first group comprised 16 personnel from the 1st Medical Battalion who were given two days of classroom instruction two weeks prior to the field exercises. The first day of training consisted of a lecture covering M3(B) assembly and operation. The second day consisted of hands-on training, with each student given time to become familiar with the various medical sensors, the computer, and the clinical support functions. Each student was afforded the time to assemble an abbreviated discharge summary. A question-and-answer period at the end of each day prompted additional comments from the users.

The second group consisted of MAP personnel who were instructed in M3(B) capabilities by the 1st Medical Battalion personnel and trainers. This training was provided two days prior to the casualty exercise in a less structured setting than that received by the Medical Battalion personnel but, as before, students received instruction followed by hands-on individual training. Comments regarding the M3(B) were recorded as well.

Field-Testing

Observations

The Forward Resuscitative Surgery Seminar[4] and the Patient Workload Generator[5] (PATGEN) were used to create 20 patient conditions (PCs) encompassing a range of illness and injury severity and types (Appendix D). These 20 PCs were used in the casualty exercise conducted at Camp Pendleton. Off-site moulaging of casualties was performed by the Medical Education and Training Services. Each patient was moved through the surgical company MTF and was administered care using the M3(B) and then again without benefit of the M3(B). The patient flow followed the functional areas within the MTF as appropriate (i.e., Triage, Shock/Surgical Trauma [SST], Operating Room [OR], and Ward). In all cases where a patient was designated as an M3(B) casualty, a PIC card was used for facility registration. The PIC cards had the patient's demographic information encoded. Non-M3 patients were manually registered using information on the surgical company's standard Trauma Resuscitation Form and/or the Standard Form 600-Chronological Record of Medical Care.

Observational data were recorded on data sheets designed to capture start and stop times for clinical activity at three of the locations within the surgical company: SST, OR, and Ward. These data collection sheets are shown in Appendix E. Comments and operational notes were entered on the data sheets. The caregiver type using the M3(B) was also recorded, however, data analysis to determine differences in speed between caregiver groups was not calculated due to the small sample sizes.

User Questionnaire

A questionnaire was designed to gather the caregivers' assessment of M3(B) performance. Questions regarding training, M3(B) clinical sensors, imaging, annotations, data extraction, recall, consolidation, and overall suitability in a variety of scenarios were included. Anonymity of respondents was maintained, although some demographic data were taken to ascertain differences due to job title. The questionnaire is included in Appendix F.

Results

Laboratory Testing

The results of the laboratory testing demonstrated that the M3(B) met the design criteria. Table 2 summarizes the relationship of eight M3(B) requirements to the hardware and software.

Table 2. Relationship Between the Requirements and the Hardware and Software

Requirement	Hardware	Software
PIC Read	External to LCU	M3 Labview®
Ultrasound with Doppler	External to LCU	COTS
Imaging	Internal to LCU	M3 Labview®
Navy Medical Configuration Definition for COE	Internal to LCU	M3 Labview®
Improved GUI	Internal to LCU	M3 Labview®
Patient Record	Internal to LCU	M3 Labview®
Temperature (manual entry)	External to LCU	M3 Labview®
General scope/nasopharyngeal	External to LCU	COTS
GPS	External to LCU	COTS

Weight and volume of the M3(B) in each of its transit cases were recorded. All three cases have identical dimensions – 18 inches x 15 inches x 22 inches. Volume of each case is 3.43 cubic feet. The case containing the LCU, its power box and cables weighed 45 pounds. The case containing the ultrasound and its sensor probes weighed 38 pounds. The case of accessories (isolation transformer, GPS, scope, camera, SmartCard reader, miscellaneous cables) weighed 39 pounds. A handful of items were not accommodated in the transit cases – GPS battery charger, vehicle power adapter cables, and any consumables. Weights do not include the printer, spare and repair parts.

The M3(B) battery was allowed to run on battery power (only) with just the M3(B) Main Screen open. The battery was depleted at the end of 65 minutes of operation. After full recharging, operation resumed with pulse oximetry (SPO_2) and ECG monitoring engaged. The battery was depleted at the end of 57 minutes of operation. A third battery life test was accomplished with BP operating at one-minute intervals in addition to SPO_2 and ECG monitoring. Use of the cuff pump depleted the battery in 55 minutes of operation.

Field-Testing

Results of the field testing were obtained by direct observation of M3(B) use, the questionnaire administered to the medical providers who used the M3(B), and general comments from numerous users and sources.

Observations: Timing Data

The initial patient flow of 10 M3(B) and 10 non-M3(B) patients per day was modified to a two-day total of 12 M3(B) and 9 non-M3(B) patients per day. Patient type and day are presented in Table 3.

Table 3. Patient Flow In Casualty Exercise

NHRC Patient Condition	Day 1	Day 2	Notes
1-Traumatic amputation	WITH M3	N/A	
2-MIW, gunshots to abdomen	N/A	WITH M3	CAN COMPARE #2 WITH&W/O
2-MIW, gunshots to abdomen	N/A	WITHOUT M3	
3-Respiratory distress, trauma	N/A	N/A	
4-Shaped charge, lower leg	WITHOUT M3	WITH M3	CAN COMPARE #4 WITH& W/O
5-Open thigh laceration	N/A	WITH M3	
6-Multiple frag. wounds, ab'men	WITH M3	N/A	
7-Flechettes, lower abdomen	N/A	WITH M3	
8-Flechettes, chest and thorax	N/A	N/A	
9-Gunshot wound to head	WITH M3	N/A	CAN COMPARE #9 WITH& W/O
9-Gunshot wound to head	WITHOUT M3	N/A	
10-Open fracture of upper arm	WITHOUT M3	N/A	
11-Multiple fragment wounds	WITH M3	N/A	
12-Acute respiratory disease	WITH M3	N/A	CAN COMPARE #12 WITH& W/O
12-Acute respiratory disease	WITHOUT M3	N/A	
13-Heat exhaustion	WITHOUT M3	N/A	
14-Dermatophytosis	N/A	N/A	
15-Diarrhea	WITH M3	N/A	
16-Febrile Illness	WITHOUT M3	N/A	
17-Wound to forearm	N/A	WITHOUT M3	
18-Wound to lower leg	WITH M3	N/A	
19-Wound to foot, fractured	WITH M3	N/A	
20-STD	WITHOUT M3	N/A	

The six observers entered start and stop times for activities for each of the 23 patients. The start and stop times were converted to elapsed times after the exercise concluded. At the same time, the caregiver's code was entered, where appropriate, to allow investigation of time differences (if any) between caregiver groups.

Unfortunately, there were fewer opportunities to compare data directly for any given patient in an M3(B) versus a non-M3(B) condition. Four patients were recorded in both conditions. Of these, two pairs (PC2 and PC9) were not used because the patients were immediately declared expectant; minimal entries were made into each set of records. Comparisons were expanded to include M3(B)/non-M3(B) pairings based on similarity and severity of injury. This produced one additional pairing, PC15 with M3(B) and PC 16 without M3(B).

A second mitigating condition occurred when patients were being processed without an M3. Vital signs (BP, SPO2, Heart Rate, Temperature) were verbalized (i.e., simulated,

by the 1st Medical Battalion physician observers). For the nine non-M3(B) patients, clinical sensors were employed in seven of a possible 72 operations. For 12 M3(B) patients, clinical sensors were used in 43 of 96 possible operations (45% of the time).

The speed at which steps were performed using the M3(B) and conventional methods was compared for similar patient conditions. Definite patterns emerged:

Patient Registration: The average length of time needed to register a patient using the PIC was three minutes. Registration of the non-M3(B) patients using the standard form averaged five minutes.

Blood Pressure and SPO_2 Rate: The average time required in the SST to gather BP and SPO2 information using the M3(B) was one minute, while the average time using conventional methods was seven minutes.

ECG Monitoring: The average time taken to monitor two patients' ECG in the SST was three minutes using the M3(B). No SST patients' ECGs were monitored by non-M3(B) means. In the Ward, one patient was monitored using M3(B) for ten minutes. At that location, the average time to monitor two patients' ECG by conventional methods was two minutes.

Annotations: The widespread use of annotations in M3(B) was evident; 18 annotations were taken for the 12 patients. Time spent on a single annotation ranged from one to ten minutes. Average time was just under five minutes. The amount of time spent on annotation appeared to be inversely proportional to the severity of the injury. Annotations were short and precise in cases where caregivers were occupied with providing immediate care in the SST. In the Ward, more time was devoted to lengthier annotations. For the non-M3(B) patients, time entries for annotations are for the handwritten notes in the Trauma Resuscitation Form. Three such occurrences averaged 11 minutes.

Image Capture: This feature, found only in the M3(B), was used eight times for 12 patients at an average time of one minute per image.

Ultrasound with Doppler: This M3(B) feature was used once in the SST for four minutes for a shrapnel-wound casualty and once in the Ward for eleven minutes for a mine-blast casualty.

Nasopharyngoscope: Similarly, the nasopharyngoscope was used once in the SST and twice in the Ward. Average length of use was slightly less than two minutes. All three cases were open-wound patients.

Corpsmen performed the majority of M3(B) clinical and support tasks. Twelve corpsmen, two nurses and one doctor used the M3(B). Comparisons in proficiency of using the M3(B) among the groups cannot be made because of the small sample sizes for nurse and physician.

Questionnaire

Thirteen respondents returned completed questionnaires. Responses were summarized for items relating to training, M3(B)'s clinical sensors, imaging, annotations, data extraction, storage, and overall suitability in a variety of scenarios. The questions were grouped according to the objectives noted in Figure 3: clinical capabilities, footprint, productivity, and user satisfaction. The questions were rated from 1 (no) to 4 (yes). Data from one respondent were not used because only one question had been answered. Means and standard deviations were computed for each item.

Experience and Training Level: Respondents reported they had prior experience using vital signs monitoring equipment. The M3(B) was judged as easy to learn (M=3.5; SD=.8) and the amount of training received on the M3(B) was rated as adequate (M=2.7; SD=.90).

Clinical Capabilities: The caregivers responded positively to the statement that the M3(B) increased their clinical capabilities (M=3.4; SD=1.0). They liked the additional medical capabilities (M=3.4; SD=1.0) and believed that the M3(B) would improve clinical care (M=2.8; SD=1.0).

Footprint: The medical providers responded positively to having the clinical sensors in a single "package" rather than individual devices (M=3.2; SD=1.0). However, respondents reported the use of the M3(B) would not make personnel available to perform other jobs (M=2.2; SD=1.1) nor affect the number of medical evacuations (M=2.0; SD=2.0).

Productivity: Medical providers were also asked questions regarding the impact of the M3(B) on productivity. They reported that the M3(B) would improve patient tracking (M=3.2; SD=.9). The respondents felt that the M3(B) was somewhat helpful in making a rapid diagnosis and developing a treatment plan (M=2.3; SD=1.1) and that it was slightly easier to use for documenting relevant patient data (M=2.4; SD=.9) compared with the currently available methods.

Users' Satisfaction: As previously mentioned, care providers were satisfied with the clinical capability the M3(B) offers. They reported that the M3(B) made patient registration a little easier (M=2.6; SD=1.0) and that they would be willing to use the M3(B) (M=2.8; SD=1.0). The respondents did, however, report that the M3(B) was somewhat difficult to set up (M=3.1; SD=1.0).

Clinical Sensors: Medical providers were asked their opinion of M3(B) individual clinical sensors: BP, ECG, SPO_2, Ultrasound with Doppler, nasopharyngoscope, and manual temperature input. Table 4 provides the summary of responses regarding the clinical sensors. Responses regarding the M3(B) BP in comparison with current methods and improving efficacy were all moderate. ECG on M3(B) was regarded as less suitable than current methods. The respondents felt strongly that the ECG was not better suited for determining efficacy of therapeutic approach. Users expressed no strong feelings

regarding SPO_2. Current methods used to display SPO_2 were regarded as better than those in M3(B). Ultrasound was rated as useful in determining the efficacy of treatment approach but was found lacking in the usefulness of the displays. Responses on the usefulness of still imaging were moderate. Although the scope was not used much during the casualty exercise, respondents reported that it could be somewhat useful in determining treatment efficacy. The temperature displays, conversions, and perceived usefulness for care were positively reported. Overall, there was no evidence that the BP, ECG, and SPO_2 devices and displays were regarded as better than the ones currently in use.

Table 4. Questionnaire Responses Regarding Clinical Sensors

Clinical Sensor	Device better than current?		Display better than current?		Better for determining treatment?		Better for treatment efficacy?		Displays easy to understand?	
	M	SD	M	SD	M	SD	M	SD	M	SD
BP	2.3	1.0	2.4	.8	2.5	1.2	2.6	1.2	X	X
ECG	1.9	.9	1.6	.9	1.7	.9	1.4	.5	X	X
SPO_2	2.5	1.2	1.9	1.0	2.1	1.2	2.0	1.1	X	X
Ultrasound	X	X	X	X	2.6	1.2	2.8	1.2	1.9	.9
Images	X	X	X	X	2.2	1.1	2.4	1.1	X	X
Scope	X	X	X	X	2.6	1.5	2.8	1.5	2.4	1.3
Temp	X	X	X	X	X	X	2.2	1.3	3.3	1.1

Note: "X" = Not Applicable. The questions were rated from 1 (no) to 4 (yes).

Clinical Support: A series of questions related to the clinical support aspects of the M3(B). These are summarized in Table 5. The GPS screen itself was well liked, but the actual location documentation received moderate responses. SmartCard information displayed directly on the screen was extremely well received, and patient registration with SmartCard was regarded as far easier than manual entry. Similarly, patient tracking was considered easier. Responses were moderate to questions about still imaging. Visual alarms were not of themselves viewed positively, especially for problem identification.

Table 5. Questionnaire Responses Regarding Clinical Support Functions

Clinical Support Functions	Like?		Easier than previous?		Useful for determining treatment?		Easier identification of problems?	
	M	SD	M	SD	M	SD	M	SD
GPS screen	3.1	1.0	X	X	X	X	X	X
Documentation location	X	X	2.6	1.2	X	X	X	X
SmartCard screen	3.7	.5	X	X	X	X	X	X
Patient registration	X	X	3.3	.7	X	X	X	X
Patient tracking	2.9	.8	X	X	X	X	X	X
Still images	2.7	1.2	X	X	2.2	1.1	X	X
Visual alarms	X	X	X	X	X	X	1.5	1.2

Note: "X" = Not Applicable. The questions were rated from 1 (no) to 4 (yes).

Management Information Support: Information support functions were addressed in a series of questions. Table 6 summarizes the findings. M3(B) users were enthusiastic about being able to review prior data on-screen as well as being able to correct input errors before becoming part of the record. Communications options, such as electronic mail, were not put to use in this particular field exercise due to lack of connectivity at the site. Responses to these questions were generally negative. However, store and forward, reporting, and communications were used extensively with TMCS during the May 1998 exercise in Thailand, Cobra Gold.

Table 6. Questionnaire Responses Regarding Management Information Support Functions

Clinical Support Function	Able to correct?		Able to manipulate?		Able to review?		Comm functions useful?	
	M	SD	M	SD	M	SD	M	SD
Prior data	X	X	X	X	3.1	1.2	X	X
Input errors	3.0	1.5	X	X	X	X	X	X
Use of annotations	3.0	1.3	X	X	X	X	X	
Manipulate files	X	X	2.8	1.5	X	X	X	X
Comm functions	X	X	X	X	X	X	1.8	1.1
Able to send e-mail	X	X	X	X	X	X	1.6	1.3

Note: "X" = Not Applicable. The questions were rated from 1 (no) to 4 (yes).

The final series of questions pertained to the users' perceptions of the types of missions for which the M3(B) might be suited. A summary of results is found in Table 7. When asked whether the M3 workstation would be useful in a variety of scenarios, respondents reported that it would be most useful for shipboard, sick call and humanitarian operations. Respondents felt the M3 workstation would be least useful during medical evacuations.

Table 7. Questionnaire Responses Regarding Use in a Variety of Scenarios

M3(B) usable in----?	Mean	Std deviation
-Shipboard	3.5	.9
-Sick call	3.5	.9
-Humanitarian	3.0	1.2
-Operations from sea	2.8	1.3
-Disaster relief	2.6	1.1
-Medevacs	2.5	1.0

Note: The questions were rated from 1 (no) to 4 (yes).

Discussion and Recommendations

During the development of the M3(B) prototype, through participation in many demonstrations and exercises, and the laboratory and field-testing, much was learned regarding the design and capabilities of the M3(B) and its configuration. The following discussion and recommendations reflect the most appropriate changes that could be implemented.

Laboratory Data

Laboratory data were gathered from a number of sources beginning with factory acceptance and continuing to post-exercise testing. Users and evaluators generally agree that the M3(B) meets the design and performance expectations as delivered. The five-minute autosave function was positively viewed, as were the self-diagnostic programs for the BP, ECG and SPO_2 monitors. Four hardware failures (Video board, SPO_2 board, loose connection, video camera) were recorded during the use of the three systems. The repairs were performed and the failures were not considered indicative of design problems nor did they represent any failure trend. During laboratory use, some desired improvements were noted as well. Consumables required for operation of the M3(B) should, ideally, be limited to those already found in the Marine Corps' Authorized Medical Allowance List (i.e., water-soluble jelly for the ultrasound and ECG). While battery life was found to differ by more than a half an hour between two M3(B)s operating in the field without AC power, no exhaustive studies were conducted on battery life under different controlled load nor between different systems. The spare and repair parts that might be required for the M3(B) have not been formally defined.

Training

Training on the M3(B) assumes a basic knowledge of computers and a familiarity with the Windows NT® environment. Because many of the users were not sufficiently computer literate, extensive documentation beyond that provided in the User Manual is recommended. Although the M3(B) User Manual was well received by the users, a more procedural, task-oriented version should be written, which outlines individual steps toward accomplishing specific objectives.

Clinical software in the M3(B) is transparent to the user in the case of the BP, ECG, and SPO_2 so that little training is required beyond the selection of clinical sensor display, time settings, and alarm settings. However, the ultrasound software demonstrated the need for specific prior training in its operation. Training should include familiarity with the software-controlled, user-defined functions of the system such as icon versus pull-down menu control, mode selections, selection and setting of sensor and display parameters, data recording and recall, annotations, and report setup and generation. It is recommended that specific training be provided for ultrasound, whether it be for that system currently used with M3(B) or a subsequent system chosen for the M3 workstation.

Scenario-Based Considerations

Although a number of caregivers reported that the M3(B) was useful for patient conditions ranging from the severely wounded to ambulatory, they noted that the M3(B) was not well-suited to Echelon I conditions or to triage. Its size and weight were the limiting factors most often mentioned. It was, however, regarded as most useful within the SST and Ward.

The M3(B) appears useful in a variety of environments. Even though there was not an opportunity in this exercise for evaluation of sick call or Operations Other Than War, caregivers reported that the M3(B) workstation would lend itself to those scenarios. It also appears that it would be useful in more remote and austere environments. Shipboard use on both small-deck and large-deck vessels is indicated. The use and evaluation of the M3(B) workstation aboard the USS Coronado during the RIMPAC exercises of August 1998 provided additional user feedback regarding the use of the M3(B) in shipboard medical spaces.

Configuration

The physical dimensions, the number and type of clinical sensors, and the software and hardware packaging were all user concerns. M3(B) setup, transportability, and consumable requirements were topics of discussion as well. The M3(B) provided the caregivers a variety of clinical sensors and data packages, which were well received. The users, evaluators, and designers agreed that the packaging of the M3 workstation should result in reduced weight, volume, number of separate items, and number of part connections. It is recommended that the M3 workstation incorporate clinical sensors that are more compact and less complex. Wherever possible, they should be integral to the LCU or combined externally into the smallest package possible requiring few connections. The connections for cabling should be unambiguous. It is also recommended to integrate sensors that are environmentally ruggedized. The ultrasound and scope should be more compact, even at the expense of some of the many capabilities they exhibited in M3(B). It is recommended that digital X-ray and automatic temperature be evaluated for inclusion into the M3 workstation sensor suite.

It is recommended that, in addition to reduction in weight and size, any shipping containers for M3 be multi-functional. It is desirable to have the transit cases double as work surfaces or as enclosures to the operating workstation. For a further footprint reduction, wireless transmission of clinical sensor data to the M3 workstation should be incorporated. A spare parts list as well as a list of consumable items should be developed. The availability of spare parts, consumable items, and minor repair items should be determined. As the M3 workstation is defined, an integrated logistics plan should be developed.

Users expressed a desire for added technologies and capabilities. Voice-activated data recording, wireless communication, acquisition and transmission of clinical data were mentioned.

Clinical Functions

Overall, the users felt that the clinical devices were suitable and adequate. Sensor availability, suitability, and ease of use were considered. Users gave their impressions on how well patient data were captured and the care provided. While the sensor suite was generally viewed as adequate, several caregivers stated that the ultrasound and nasopharyngoscope might not be needed with each M3(B), but rather one or two units for

each surgical company might be adequate. A number of users expressed a desire to have vital sign acquisition begin immediately prior to a patient being registered. Also, the desirability of wireless acquisition of vital signs was mentioned. Visual alarms were not judged to be useful, however, auditory alarms in addition to visual alarms were perceived as desirable because they would allow for greater flexibility for the caregivers to perform other tasks.

Additional clinical devices mentioned included digital x-ray, whose results would be stored, viewed, and forwarded from the M3; noninvasive temperature entered automatically; and blood gas assessment. Emerging technologies that might make additional sensors available for the M3 workstation will continue to be evaluated as development continues.

Clinical and Management Information Support

In addition to the clinical sensors, the M3(B) provides the capability to assemble and portray clinical data to assist clinical decision-making processes. Users evaluated and commented on the manner in which patient data are summarized, displayed, stored, recalled, and forwarded. The use of PIC for patient registration was reported as useful both for its speed and accuracy. Users, nonetheless, wished to see a write capability in M3(B) in addition to the read capability. This would allow medical data and annotations to be recorded onto the card from the workstation. Users noted that the M3(B) provided ample opportunities and screens to create annotations. However, the M3(B) does not allow for simultaneous vital signs viewing and annotation writing. Multiple-entry annotations in their own Microsoft® folder were perceived to be of added benefit. Some users reported that the M3(B) required too much typing. Retrieval of patient records was reported as easy to accomplish, particularly prior to patient discharge. The ability to host other programs was positively viewed and would allow easy access to drug, and nuclear, biological, and chemical (NBC) information. The hosting of medical reference programs on the LCU would also reduce the weight and space of paper volumes.

The communications capability which M3(B) provides for programs such as TMCS demonstrate that the M3 workstation is capable of effective Internet transmission. As with other types of data transmissions, TMCS communications were constrained by traffic volume, line quality, and available bandwidth. TMCS users at Cobra Gold also provided a detailed critique of the TMCS program.

SmartCard Implementation

The M3 should enhance the interface capability with the SmartCard to include not only the read function but also write functions. The users agree that the SmartCard is useful for patient registration and the M3 workstation should take advantage of capturing other medically relevant information. It is recommended that any information already resident on the card such as allergies, medications, or previous conditions be downloaded from the SmartCard to the M3 workstation. This information may be useful in the delivery of medical care. The capability to write patient demographics, patient encounter

information, patient disposition, and order information from the M3 workstation to the SmartCard should be developed. In addition, the M3 workstation should be capable of transferring the relevant medical encounter data to the other MTFs that are responsible for providing follow-on medical treatment. This transfer of information is extremely important for maintaining the continuity of patient care.

Multi-Patient Monitoring

One of the most frequently mentioned capabilities lacking in the M3(B) is multi-patient monitoring. The current M3(B) allows for the monitoring of only one patient at a time. Even though other administrative or management functions could be accomplished simultaneously, it still was one patient per computer. Since MPM was reported as the single most important medical requirement, it is recommended that the current M3 configuration be re-examined to accomplish this function. The M3 workstation should be flexible enough to allow clinical monitoring of one to eight patients. This simultaneous monitoring of multiple patients per workstation would allow personnel to perform other duties.

Relational Database

It is recommended that the M3 workstation incorporate a relational database system to capture and store sensor-generated data. The M3 workstation should provide easy-to-use tools for data searches, retrieval, display, and reporting. Other software applications should be able to access the database, extract or summarize information, and forward that information for use in command and control, medical logistics, and clinical reports.

Re-engineering of Work Processes

Insertion of new technologies can affect the way work is performed. Comments were made regarding processes surrounding the use of M3(B). For example, the use of the PIC may alter the way patient administration, patient status, and patient tracking tasks are performed. Also, there was some discussion about the placement and networking of M3(B)s throughout the MTF. This placement and networking capability would allow for patient information storage for a variety of purposes, such as patient documentation, ordering, posting and review of laboratory and x-ray results. Such items as configuration and location of M3(B)s within the MTF were noted.

Since improvements to the configuration of the M3 workstation could have an impact on current work processes, efforts need to be made to revalidate operational requirements. The patient flow, the perceived workload, the speed with which the work gets done, and the interaction among the functional areas are potentially impacted by improving the work processes. The ongoing dialogue between developers, users, and evaluators allows for communicating possible opportunities to improve work processes.

Based on these results, it appears that a network-centric approach to automating medical care on-site, and to the transmission of medical information between MTFs, should be

explored. Future work should focus on the integration of present and future sensors, clinical devices, and medical command and control programs into a medical workstation. This medical workstation would integrate medical software with a common searchable database to provide a medical information infrastructure for operational environments.

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Appendix A: List of Acronyms

M3(B) Workstation List of Acronyms

ATP	Acceptance Test Procedure
BP	Blood Pressure
CD-ROM	Compact Disk Read Only Memory
COE	Common Operating Environment
COTS	Commercial Off-The-Shelf Software
DBSS	Defense Blood Support System
DII	Defense Information Infrastructure
DOD	Department of Defense
ECG and EKG	Electrocardiogram
FDA	Food and Drug Administration
FQT	Formal Qualification Test
GPS	Global Positioning System
GUI	Graphic User Interface
IT21	Information Technology in the Twenty-first Century
LCU	Lightweight Computer Unit
M3	Mobile Medical Monitor (Medical Workstation)
MAP	Medical Augmentation Program
METS	Medical Education and Training Services
MPM	Multi-Patient Monitoring
MS	Microsoft
MTF	Medical Treatment Facility
NBC	Nuclear, Biological, and Chemical
NHRC	Naval Health Research Center
NMIMC	Naval Medical Information Management Center
OEM	Original Equipment Manufacturer
OR	Operating Room
PC	Personal Computer (terminology pertains to IBM/IBM clones)
PC	Patient Condition/Code
PIC	Personal Information Carrier
QA	Quality Assurance
SAIC	Science Applications International Corporation
SF600	Standard Form 600
SRAR	Software Requirements Analysis Report
SST	Surgical/Shock Trauma
STD	Sexually Transmitted Disease
STD	Software Test Descriptions
TMCS	Theatre Medical Core Services
TRF	Trauma Resuscitation Form
UUT	Unit Under Test

Appendix B: M3(B) Workstation Evaluation Criteria

	Increase Clinical Capabilities									
M3(B) Capability	Data Integrity	Accuracy	Clinical Sensors	Usability	Practicality	Durability	Reliability		Data Transmission	
							Lab	Fld	Lab	Fld
1. 12-Lead ECG	2	2	1,4	1	1	1,4	1	1	2	2
2. BP	2	2	1,4	1	1	1,4	1	1	2	2
3. Pulse Oximetry	2	2	1,4	1	1	1,4			2	2
4. Nasopharyngoscope		2	1,4	1	1	1,4	1	1	2	2
5. Ultrasound with Doppler		2	1,4	1	1	1,4	1	1	2	2
6. Temperature			1,4						2	2
7. Imaging	2	2	1,4	1	1	1,4	1	1	2	2
8. GPS		2		1	1	1,4	1	1	2	2
9. GUI (Selection, Capture and Reporting Clinical Data)			1,4	1	1				2	2
10. Card reader				1	1	1,4			2	2
11. Integrated M3(B) sensors	2	2	1,4	1			1	1	2	2
12. M3(B) workstation (TMCS, NT)				1	1	1,4			2	2
13. LCU				1	1	1,4				

1= User questionnaires and surveys
2= Observations check sheets and charts
3= Follow on provider questions
4= Interviews
5= After actions

Appendix B: M3(B) Workstation Evaluation Criteria (Cont'd)

	Increase Productivity and Maintain Readiness					
M3(B) Capability	Training	Clinical Sensors	Data Capture		Data Transmission	
			Lab	Fld	Lab	Fld
1. 12-Lead ECG	1,5	1	2 (FQT)	2	2	2
2. BP	1,5	1	2 (FQT)	2	2	2
3. Pulse Oximetry	1,5	1	2 (FQT)	2	2	2
4. Nasopharyngoscope	1,5		2 (FQT)	2	2	2
5. Ultrasound with Doppler	1,5	1	2 (FQT)	2	2	2
6. Temperature	1,5	1	2 (FQT)	2	2	2
7. Imaging	1,5	1	2 (FQT)	2	2	2
8. GPS	1,5		2 (FQT)	2	2	2
9. GUI (Selection, Capture, and Reporting Clinical Data)		1	2 (FQT)	2	2	2
10. Card Reader			2 (FQT)	2	2	2
11. Integrated M3(B) Sensors	1,5	1	2 (FQT)	2	2	2
12. M3(B) Workstation (TMCS, NT)	1,5		2 (FQT)	2	2	2
13. LCU	1,5					

1= User questionnaires and surveys
2= Observations check sheets and charts
3= Follow on provider questions
4= Interviews
5= After actions group

Appendix B: M3(B) Workstation Evaluation Criteria (Cont'd)

	Increase Provider Satisfaction				
M3(B) Capability	Durability	Usability	Practicality	Clinical Support Function	Training
1. 12-Lead ECG	1,4	1	1,3		1,5
2. BP	1,4	1	1,3		1,5
3. Pulse Oximetry	1,4	1	1,3		1,5
4. Nasopharyngoscope	1,4	1	1,3		1,5
5. Ultrasound-with Doppler	1,4	1	1,3		1,5
6. Temperature					1,5
7. Imaging	1,4	1	1,3		1,5
8. GPS	1,4	1	1,3	1,2	1,5
9. GUI (Selection, Capture and Reporting Clinical Data)		1	1,3	1,2	
10. Card reader	1,4	1	1,3	1,2	
11. Integrated M3(B) sensors		1			1,5
12. M3(B) workstation (TMCS, NT)	1,4	1	1,5		1,5
13. LCU	1,4	1	1,5		1,5

1= User questionnaires and surveys
2= Observations check sheets and charts
3= Follow on provider questions
4= Interviews
5= After actions group

Appendix B: M3(B) Workstation Evaluation Criteria (Cont'd)

	Reduce Footprint					
M3(B) Capability	Training	Data Capture		Logistical Support	Durability	Mgt. Support Function
		LAB	FLD			
1. 12-Lead ECG	1,5	2	2	2	1,4	
2. BP	1,5	2	2	2	1,4	
3. Pulse oximetry	1,5	2	2	2	1,4	
4. Nasopharyngoscope	1,5	2	2	2	1,4	
5. Ultrasound with Doppler	1,5	2	2	2	1,4	
6. Temperature	1,5	2	2			
7. Imaging	1,5	2	2	2	1,4	
8. GPS	1,5	2	2	2	1,4	
9. GUI (Selection, Capture and Reporting Clinical Data)		2	2			1,2,4
10. Card reader		2	2	2	1,4	
11. Integrated M3(B) sensors	1,5	2	2	2		
12. M3(B) workstation (TMCS, NT)	1,5	2	2	2	1,4	1,2,4
13. LCU	1,5			2	1,4	

1= User questionnaires and surveys
2= Observations check sheets and charts
3= Follow on provider questions
4= Interviews
5= After actions group

Appendix C. Evaluation of Laboratory Testing

LINE REF	USER NAME	ACTIVITY	START TIME	FINISH TIME	ELAPSED TIME/ OCCURRENCES	NOTES
1		SET-UP AND INTERCONNECT				
2		POWER MODULE (Pg. 4)				
3		ISOLATION TRANSFORMER (Pg. 5)				
4		MODEM (Pg. 5, 22)				
5		GPS (Pg. 6, 23)				
6		ULTRASOUND (Pg. 6, 25)				
7		BP CUFF (Pg. 6, 28)				
8		ECGandSPO2 LEADS (Pg. 6, 30, 32)				
9		PIC READER (Pg. 6, 29)				
10		NASOPHARYNGEAL SCOPE (Pg. 7, 33)				
11		VIDEO CAMERA (Pg. 7, 35)				
12		PRINTER (N/A)				
13		LOGGING IN (PG. 8)				
14		USER NAME, PASSWORD (PG. 8)				
15		GPS ACTIVATE (PG. 8)				
16		PATIENT REGISTRATION (PG.8)				
17		LOCATION UPDATE (PG. 9)				
18		GPS AVAILABLE (PG. 23-24)				
19		MANUAL ENTRY				
20		ADMISSION SCREEN (PG. 9)				
21		PIC AVAILABLE (PG. 29)				
22		MANUAL ENTRY				
23		DEMOGRAPHICS (PG. 10, 14)				
24		FORMAT VIOLATIONS				
25		TEXT ENTRIES				
26		EDITING (PG. 15)				
27		WHEN PATIENT OPEN				
28		WHEN PATIENT CLOSED				
29		WHEN PATIENT DISCHARGED				
30		DATA RETRIEVAL (CLOSED, ARCHIVED)				
31		ENCOUNTERS (PG. 11)				
32		TEXT ENTRIES (PG.11)				
33		RECORD/SAVE DATA (PG.11)				
34		M3(B) MAIN SCREEN (PG. 12)				
35		FILE (PG.12)				
36		REPORT (PG.12, 18-19)				

Appendix C. Evaluation of Laboratory Testing (cont'd)

LINE REF	USER NAME	ACTIVITY	START TIME	FINISH TIME	ELAPSED TIME/ OCCURRENCES	NOTES
37		NAVIGATOR SCREEN WHEN NOT DIS'CHD				
38		TIME RANGE SELECTIONS				
39		DATA SELECTION				
40		SENSOR SELECTION				
41		NOTES SELECTION				
42		EDITING AT NAVIGATOR SCREEN				
43		EDITING AT REPORT SCREEN				
44		SEND TO PRINTER				
45		SAVE FOR STORE AND FORWARD				
46		SEND TO MAIL RECIPIENT				
47		USE OF "CANCEL"				
48		DISCHARGE (PG. 12, 17)				
49		CONTINUE WITH FIELDS EMPTY				
50		GENERATE A REPORT (PG. 17)				
51		OPTIONS (PG.12)				
52		ECG SETUP (PG. 12, 13)				
53		BP SETUP (PG. 12, 13)				
54		ALARM SETTINGS (PG. 12)				
55		VIEW (PG. 13)				
56		TRENDS (PG. 13)				
57		MULTI-LEAD ECG (PG. 13)				
58		PATIENT DATA (PG. 13)				
59		HELP (PG. 13, 19)				
60		ADMINISTRATION (PG. 13)				
61		NOTEPAD (PG. 20)				
62		WORD (PG. 20)				
63		EXCEL (PG. 20)				
64		POWERPOINT (PG. 20)				
65		CUMULATIVE USE				
66		RECORD APPLICATIONS IN USE				
67		USE AT PATIENT ALARM CONDITION				
68		COMMUNICATIONS (PG. 13)				
69		TMCS (PG. 13)				
70		NETSCAPE (PG. 20)				
71		EUDORA (PG. 20)				
72		REAL-TIME DATA DISPLAY (PG. 13)				

Appendix C. Evaluation of Laboratory Testing (cont'd)

LINE REF	USER NAME	ACTIVITY	START TIME	FINISH TIME	ELAPSED TIME/ OCCURRENCES	NOTES
73		ECG (PG. 32)				
74		BP (PG. 28)				
75		SPO2 (PG. 30-31)				
76		VIDEO – CAMERA (PG. 35)				
77		VIDEO – ULTRASOUND (PG. 25-27)				
78		VIDEO – NASOPHARING'L SCOPE (PG.33-34)				
79		DATA CAPTURE (PG. 13)				
80		ECG (PG. 32)				
81		EFFECT OF EXTENDED ECG LOGGING				
82		BP (PG. 28)				
83		SPO2 (PG. 30)				
84		VIDEO – CAMERA (PG. 35)				
85		VIDEO – ULTRASOUND (PG.25-27)				
86		VIDEO – NASOPHARING'L SCOPE (PG.33-34)				
87		VIEW TRENDS (PG. 14)				
88		TIME RANGE SELECT AND VIEW				
89		PRINT				
90		WRITING AN ANNOTATION (PG. 15)				
91		F KEY and BUTTON FOR SCREEN ACCESS				
92		DEFAULT CATEGORY				
93		EDITING				
94		ENTERING TEMPERATURE (PG. 15)				
95		ACCESS SCREEN				
96		ENTRIES				
97		EDITING				
98		USE OF MODEM (PG. 22)				
99		USE OF ULTRASOUND (PG. 25-27)				
100		ACQUIRING PERCEPTION SOFTWARE				
101		SETUP				
102		PATIENT RECORD OR FIND				
103		PROBE SELECTION/SCALING				
104		BATTERY LIFE				
105		RECORD PERIPHERALS				
106		CORRECT MISTAKES/INPUT ERRORS				
107		USE OF "CANCEL" COMMAND/DATA LOSS				
108		REFERRED TO M3(B) USER MANUAL				

109		REFERRED TO M3(B) ORIG. EQ. MFR. MANUALS				

Appendix C. Evaluation of Laboratory Testing, cont'd

KEYED TO LINE REF No.	ADDITIONAL NOTES and RESULTS and RECOMMENDATIONS

Appendix D. Patient Conditions

Field testing involves some or all of 20 patient situations constructed to measure the M3's capability as a field medical monitor. These patient conditions were developed by using information collected from the Forward Resuscitative Surgery Seminar, January 1997, and information collected from AMEDD PATGEN. The patients were admitted to the triage area at the surgical company for diagnosis, treatment, and documentation. The 20 moulaged patient situations, which reflect battlefield and sick call scenarios, are the following:

Patient #1: Patient suffers from a traumatic and complete amputation above the knee resulting from a mine blast.

Patient #2: Patient with MIW from a gunshot to the forearm, abdomen , colon, liver, small bowel and kidney.

Patient #3: Patient suffers from acute and severe respiratory distress, pneumohemothorax, resulting from a mine blast trauma. The patient has rib fractures and a wounded thorax.

Patient #4: Shaped charge anti-armor warhead injured patient's lower leg with fracture and nerve/vascular injury. Limb not salvageable

Patient #5: Patient has an open thigh laceration, penetrating deeply and associated with a fracture and nerve and/or vascular injury. Limb salvageable.

Patient #6: Patient suffers from multiple fragment wounds from antipersonnel mine: MIW chest with pneumohemothorax and abdomen with penetrating wound colon, kidney, bladder, spleen, and liver.

Patient #7: Patient flechette wounds to lower belly, wound abdominal wall and thigh requiring major debridement.

Patient #8: Patient flechette wounds to chest and wound to thorax with associated rib fractures and pneumohemothorax.

Patient #9: Patient has a gunshot wound to the head: cerebral contusion closed with depressed skull fracture moderate.

Patient #10: Patient has an open fracture of the upper arm with nerve and/or vascular injury. Limb salvageable.

Patient #11: Patient presented with multiple fragment wounds of skin and soft tissue.

Patient #12: Patient has an acute, moderate, respiratory disease.

Patient #13: Patient is suffering from heat exhaustion.

Patient #14: Unknown dermatophytosis on this patient.

Patient #15: Patient suffers from moderate diarrhea disease.

Patient #16: Patient suffers from a febrile illness in an acute state moderate severity.

Patient #17: Patient suffers from wound to the forearm without bone, nerve or vascular injury.

Patient #18: Patient suffers from a lower leg wound without fractures.

Patient #19: Patient suffers from a wound to ankle, foot, and toes with fractures and nerve/vascular injury. Limb is not salvageable.

Patient #20: Patient suffers from urethritis, a secondary cause to a sexually transmitted disease.

APPENDIX E. Evaluation of Field-Testing

EVALUATION CONDITION (CHECK ONE): WITH M3_____ WITHOUT M3_____

DATE_____ PATIENT'S CODE/CONDITION_____

REF	PROVIDER (Note 1)	ACTIVITY	START TIME	FINISH TIME	ELAPSED TIME and OCCURRENCES	No. OF ERRORS
1		**POWER UP , ACQUIRE "M3 EXEC"**				
2		**USE OF GPS FUNCTION**				
3		**REGISTER PATIENT**				
4		REGISTER PATIENT USING PIC				
5		REGISTER PATIENT MANUALLY				
6		**TAKE VITAL SIGNS AT SST**				
7		HOOK PATIENT TO ECG; MONITOR				
8		HOOK PATIENT TO BL PRESS; MONITOR				
9		HOOK PATIENT TO PO2andRATE; MONITOR				
10		SET UP PATIENT US DOPPLER; MONITOR				
11		SET UP RL SCOPE; MONITOR				
12		STILL-IMAGE CAPTURE				
13		STILL-IMAGE CAPTURE				
14		STILL-IMAGE CAPTURE				
15		TAKE PATIENT'S TEMPERATURE (NOTE 2)				
16		**TREATMENT AT SST**				
17		SET OR VERIFY VISUAL ALARMS				
18		PRIOR DATA LOCATION AND REVIEW				
19		**TAKE VITAL SIGNS AT OPERATING ROOM**				
20		HOOK PATIENT TO ECG; MONITOR				
21		HOOK PATIENT TO BL PRESS; MONITOR				
22		HOOK PATIENT TO PO2andRATE; MONITOR				
23		SET UP PATIENT US & DOPPLER; MONITOR				
24		SET UP RL SCOPE; MONITOR				
25		STILL-IMAGE CAPTURE				
26		STILL-IMAGE CAPTURE				
27		STILL-IMAGE CAPTURE				
28		TAKE PATIENT'S TEMPERATURE (NOTE 2)				
29		**TREATMENT AT OPERATING ROOM**				
30		SET OR VERIFY VISUAL ALARMS				
31		PRIOR DATA LOCATION AND REVIEW				
32		**TAKE VITAL SIGNS AT WARD**				
33		HOOK PATIENT TO ECG; MONITOR				
34		HOOK PATIENT TO B. PRESS; MONITOR				
35		HOOK PATIENT TO PO2andRATE; MONITOR				
36		SET UP PATIENT US & DOPPLER; MONITOR				
37		SET UP RL SCOPE; MONITOR				
38		STILL-IMAGE CAPTURE				
39		STILL-IMAGE CAPTURE				
40		STILL-IMAGE CAPTURE				
41		TAKE PATIENT'S TEMPERATURE (NOTE 2)				
42		**TREATMENT AT WARD**				
43		SET OR VERIFY VISUAL ALARMS				
44		PRIOR DATA LOCATION AND REVIEW				
43		**DOCUMENTATION**				
44		ENTER ANNOTATIONS (NOTES 2 & 3)				
45		ENTER ANNOTATIONS (NOTES 2 & 3)				
46		ENTER ANNOTATIONS (NOTES 2 & 3)				
47		ENTER ANNOTATIONS (NOTES 2 & 3)				
48		DEVELOP PATIENT DISCH'GE SUM'Y				
49		**TRANSMISSION**				
50		COMMUNICATIONS - USE OF PRINTER				
51		COMMUNICATIONS – USE OF INTERNET				
52		COMMUNICATIONS - OTHER				
53		USER REFERRED TO M3(B) USER MANUAL				
54		USER REFERRED TO M3(B) OEM MANUAL(S)				

NOTE 1: ENTER: "C" FOR CORPSMAN, "N" FOR NURSE, "P" FOR PHYSICIAN

NOTE 2: MULTIPLE ENTRIES FOR THIS ITEM OK. NOTE 3: DOES NOT INCLUDE SPELLING/GRAMMATICAL ERRORS

EVALUATOR_____ EVALUATION CONTROL NUMBER: _____OF_____

APPENDIX E. Evaluation of Field Testing (Cont'd)

EVALUATION CONDITION (CHECK ONE): WITH M3_____ WITHOUT M3_____

DATE_______ PATIENT'S CODE/CONDITION__________________ LOCATION___________

KEYED TO LINE REF No.	ADDITIONAL NOTES and RESULTS and RECOMMENDATIONS

Appendix F. M3(B) Workstation User Questionnaire

Identification Code : _____

Please answer the following questions. The information will be vital for establishing requirements for further development of the M3.

1. Job Title: __ Doctor __ Nurse __ Corpsmen _____ Other (please specify) 2. Medical Specialty _____

3. Rank/Rate _____ 4. Corps/Rating: _____ 5. Duty Station _____

6. Current Position _____ 7. Length of time in current position _____ Years ____ Months

The following questions are about the M3 training you received. Please circle one number for each question.

	No	Little	Some	Yes	Don't Know
8. Are you experienced with using vital signs monitoring devices (i.e., Propaqs, HP monitor, etc.)?	1	2	3	4	DK
9. Was it easy learning to use the M3?	1	2	3	4	DK
10. Was the User Manual helpful during training?	1	2	3	4	DK
11. Was the training you received adequate for the operation of the M3?	1	2	3	4	DK

Please use the scale below to answer the following questions about the M3 in comparison to currently available methods.

	No	Little	Some	Yes	Don't Know
12. Is it more practical to have sensors in one package rather than as individual devices?	1	2	3	4	DK
13. Do you like the clinical capabilities offered by the M3?	1	2	3	4	DK
14. Will using the M3 improve clinical care?	1	2	3	4	DK
15. Will using the M3 help you make a rapid diagnosis and treatment plan?	1	2	3	4	DK
16. Will using the M3 reduce patient evacuations?	1	2	3	4	DK
17. Will using the M3 reduce fatalities?	1	2	3	4	DK
18. Will using the M3 make it possible for personnel to do other jobs?	1	2	3	4	DK
19. Will using the M3 save time?	1	2	3	4	DK
20. Were better triage decisions made using the M3?	1	2	3	4	DK
21. Was documenting important clinical information better using the M3?	1	2	3	4	DK
22. Will using the M3 increase patient evacuations?	1	2	3	4	DK
23. Do you think the M3 can improve patient tracking?	1	2	3	4	DK
24. Does the M3 provide better advance notice of casualty priority?	1	2	3	4	DK
25. Does the M3 help the medical provider arrive at a medical decision quicker?	1	2	3	4	DK
26. Does the M3 help the medical provider make better evacuation decisions?	1	2	3	4	DK
27. Was it easier to document the relevant patient information using the M3?	1	2	3	4	DK

Appendix F. M3(B) Workstation User Questionnaire (cont'd)

	No	Little	Some	Yes	Don't Know
28. Was transmission of previous patient care information better using the M3?	1	2	3	4	DK
29. Do you think the M3 will improve the delivery of medical care?	1	2	3	4	DK
30. Did the M3 help you, the medical provider, do your job better?	1	2	3	4	DK
31. Did using the M3 make patient registration easier?	1	2	3	4	DK
32. Did using the M3 make patient registration faster?	1	2	3	4	DK
33. Was the overall performance of the M3 a success?	1	2	3	4	DK
34. Would patients receive care that they would otherwise not have received?	1	2	3	4	DK
35. Are you willing to use the M3?	1	2	3	4	DK
36. Was the M3 hard to set up?	1	2	3	4	DK

Please use the scale below to tell us what you thought of specific components of the M3.

	No	Little	Some	Yes	Don't Know
37. Were you able to understand the ***GPS*** screen?	1	2	3	4	DK
38. Were you able to document location using the *GPS*?	1	2	3	4	DK
39. Were you able to view the information from the *SmartCard* using the M3?	1	2	3	4	DK
40. Did using the *SmartCard reader* make patient registration easier than current methods?	1	2	3	4	DK
41. Did using he *SmartCard* make patient tracking easier than using current methods?	1	2	3	4	DK
42. Was the ***blood pressure*** device more useful for clinical care compared to current methods?	1	2	3	4	DK
43. Was the ***blood pressure*** display easy to understand compared to the current method?	1	2	3	4	DK
44. Were the ***blood pressure*** trends useful for improving clinical care?	1	2	3	4	DK
45. Was the ***blood pressure*** information more useful in determining appropriate treatment compared to current methods?	1	2	3	4	DK
46. Was the ***blood pressure*** information more useful regarding the efficacy of the therapeutic approach when compared to current methods?	1	2	3	4	DK
47. Was the ***ECG*** device more useful for providing clinical care than current methods?	1	2	3	4	DK
48. Were the *ECG* displays easier to understand than the current method?	1	2	3	4	DK
49. Was ***ECG*** information more useful in determining what treatment to provide when compared to the current method?	1	2	3	4	DK
50. Was ***ECG*** information more useful regarding the efficacy of the therapeutic approach than using the current method?	1	2	3	4	DK
51. Was the ***pulse oximetry*** device more useful for providing clinical care when compared to the current methods	1	2	3	4	DK
52. Were the ***pulse oximetry*** displays easier to understand than the current methods?	1	2	3	4	DK
53. Was ***pulse oximetry*** information more useful in determining what treatment to provide when compared to the current method?	1	2	3	4	DK
54. Was ***pulse oximetry*** information more useful regarding the efficacy of the therapeutic approach compared to the current method?	1	2	3	4	DK
55. Did you use the ***pulse oximetry*** trend option?	1	2	3	4	DK
56. Was the ***pulse oximetry*** trend information useful?	1	2	3	4	DK

Appendix F. M3(B) Workstation User Questionnaire (cont'd)

	No	Little	Some	Yes	Don't Know
57. Were the ***Ultrasound*** displays easy to understand?	1	2	3	4	DK
58. Was the ***Ultrasound*** information useful in determining what treatment to provide?	1	2	3	4	DK
59. Was the ***Ultrasound*** information useful regarding the efficacy of the therapeutic approach?	1	2	3	4	DK
60. Were the ***still images*** easy to understand?	1	2	3	4	DK
61. Was the information from the ***still imaging*** useful in determining what treatment to provide?	1	2	3	4	DK
62. Was ***still imaging*** useful regarding the efficacy of the therapeutic approach?	1	2	3	4	DK
63. Was the ***nasopharyngeal scope*** display easy to understand?	1	2	3	4	DK
64. Was the information from the ***nasopharyngeal scope*** useful in determining what treatment to provide?	1	2	3	4	DK
65. Was the information from the ***nasopharyngeal scope*** useful regarding the efficacy of the therapeutic approach?	1	2	3	4	DK
66. Do you think ***temperature*** is useful for clinical care?	1	2	3	4	DK
67. Was the ***temperature*** display easy to understand?	1	2	3	4	DK
68. Was it helpful to see ***temperature*** conversions?	1	2	3	4	DK
69. Was it useful to see ***temperature*** data displayed over time?	1	2	3	4	DK
70. Was ***temperature*** information useful regarding the efficacy of the therapeutic approach?	1	2	3	4	DK
71. Were the *visual alarms* useful?	1	2	3	4	DK
72. Did the *visual alarms* help you identify that there was a problem?	1	2	3	4	DK
73. Did you set your own ranges for the *alarms*?	1	2	3	4	DK
74. Are data displayed in a way that is readily useful to the medical provider?	1	2	3	4	DK
75. Did you use the note-taking (annotations) capability?	1	2	3	4	DK
76. Were you able to correct errors in data entry?	1	2	3	4	DK
77. Were you able to correct errors in data retrieval?	1	2	3	4	DK
78. Were you able to capture the exact information you wanted?	1	2	3	4	DK
79. Was patient file manipulation difficult?	1	2	3	4	DK
80. Were you able to review previously captured data?	1	2	3	4	DK
81. Do you think the communication functions are useful?	1	2	3	4	DK
82. Were you able to send the patient summary form using e-mail?	1	2	3	4	DK

Please answer the following questions using the scale below.
Compared to currently available methods, do you think the M3 workstation is more useful for ...

	No	Little	Some	Yes	Don't Know
83. humanitarian missions?	1	2	3	4	DK
84. disaster relief missions?	1	2	3	4	DK
85. operational maneuvers from the sea?	1	2	3	4	DK
86. shipboard use?	1	2	3	4	DK
87. sick call ?	1	2	3	4	DK
88. medevacs?	1	2	3	4	DK
89. other, please specify _____					

Appendix F. M3(B) Workstation User Questionnaire, (cont'd)

90. Compared to using (current) individual instruments and sensors, how would you rate the M3 system for its overall effect on your ability to conduct medical monitoring.

More Difficult	5	4	3	2	1	No Difference	1	2	3	4	5	Less Difficult

Thank you for your participation! **Please feel free to write any additional comments you might have. Thanks Again.**

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13. ABSTRACT *(Maximum 200 words)* Deployment of portable medical technologies supports delivery of care to deployed forces in theater operations and Operations Other Than War (OOTW). The Mobile Medical Monitor (M3) concept creates a clinical and information support system comprised of a standard battlefield computer with an integrated clinical sensor suite capable of data store and forward. The primary objective of this report is to document the evaluation of the M3(B) workstation. The evaluation was conducted to determine the extent to which the M3(B) requirements met the primary objectives of increasing clinical capabilities, productivity, provider satisfaction, and reducing footprint. Laboratory tests were conducted to evaluate the accuracy and reliability of the individual components and the fully integrated system. Training in the use of M3(B) was then given to two groups of medical personnel of the 1st Medical Battalion, Camp Pendleton, CA. Field testing was conducted at a surgical company during casualty exercises held by the 1st Medical Battalion. During the exercise, observations and objective measures were gathered. The data resulting from laboratory testing demonstrated that the M3(B) met its design criteria for hardware and software. Battery life, however, averaged nearly one hour instead of the anticipated two hours. Timing data from field observations showed that patient registration with an M3(B) was 40% faster than manual methods. M3(B) blood pressure and pulse oximetry readings averaged one-seventh the time of conventional methods. Annotations and video capture were frequently used. Ultrasound and the rhinolaryngoscope were not extensively used. Ultrasound was found to require a higher level of training than had been provided. Results from the questionnaire showed the M3(B) easy to learn and that generally the users were satisfied with the clinical sensors, although the M3(B) was perceived as difficult to set up. Respondents were positive in their reaction to integrated sensors. The M3(B) was judged to increase productivity by improving patient tracking and allowing caregivers to make a rapid diagnosis. The users reported that they considered patient registration easier and would be willing to use the M3(B) in a variety of scenarios. The ability to monitor multiple patients and the ability to write information onto the Personal Information Carrier (PIC) were recommended. The users also noted that a relational data base would enhance information support. The packaging of the M(B) should result in the reduced weight, volume, number of separate items, and number of connections and be housed in multi-purpose containers. A network-centric approach to providing medical care and transmission of medical information is indicated. Smart Card write capability, multi-patient monitoring, and a relational database are recommended.

14. **SUBJECT TERMS** Mobile medical monitor, clinical devices, multi-patient monitoring clincial data capture, PIC, store-and-forward

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